5. Sewage Monitoring

Jennifer M. Larson
Brian K. Balke

Introduction

In 1994, the Livermore site discharged approximately 1.1 million liters per day of wastewater to the City of Livermore sewer system, an amount that constitutes less than 6% of the total flow to the system. This volume includes wastewater generated by Sandia National Laboratories, California (Sandia, California), which is discharged to the LLNL collection system and combines with LLNL sewage before it is released at a single point to the municipal collection system. The wastewater contains sanitary sewage and industrial effluent and is discharged in accordance with permit requirements and the City of Livermore Municipal Code.

The effluent is processed at the Livermore Water Reclamation Plant (LWRP). As part of the Livermore-Amador Valley Wastewater Management Program, the treated sanitary wastewater is transported out of the valley through a pipeline and discharged into San Francisco Bay. A small portion of the treated effluent is used for summer irrigation of the adjacent municipal golf course. Sludge from the treatment process is disposed of in sanitary landfills.

LLNL receives water from two suppliers. LLNL's primary water source is the Hetch-Hetchy Aqueduct. Secondary or emergency water deliveries are taken from the Alameda County Flood Control and Water Quality Conservation District Zone 7. This water is a mixture of ground water and water from the South Bay Aqueduct of the State Water Project. Water quality parameters for the two sources are obtained from the suppliers and are used to evaluate compliance with the discharge permit conditions that limit changes in water quality between receipt and discharge.

Administrative and engineering controls at the Livermore site effectively prevent potentially contaminated wastewater from being discharged directly to the sanitary sewer. Waste generators receive training on proper waste handling. Environmental Protection Department (EPD) reviews facility procedures and inspects processes for inappropriate discharges. Retention tanks are used to collect wastewater from processes that might release contaminants in quantities sufficient to disrupt operations at the LWRP. Finally, to verify the success of training and control equipment, wastewaters are sampled and analyzed not only at the significant points of generation, as defined by type and quantity of contaminant generated, but also at the point of discharge to the municipal sewer system.

To ensure the integrity of the wastewater collection system, LLNL recently has pursued an aggressive assessment and rehabilitation program. During 1992 and 1993, all building drains that could be identified were tested to determine their points of discharge. Identified deficiencies, considered to be illicit connections, were classified and are being corrected; major deficiencies were immediately remedied. The retention tank infrastructure at LLNL is undergoing comprehensive evaluation and rehabilitation. Finally, preparatory to relining with a synthetic sock, the major laterals of the sanitary sewer system have been videotaped and evaluated. Major line failures have been repaired. The relining work was completed in 1994.

For facilities with installed retention tank systems, collected wastewater is discharged to the sanitary sewer only if laboratory results show that pollutant levels are within allowable limits (Grandfield 1989). LLNL has developed internal discharge guidelines for specific sources and operations to ensure that sewer effluent for the entire site complies with LLNL's waste discharge permit. If pollutant levels exceed permissible concentrations, the wastewater is treated to reduce pollutants to the lowest levels practical and below LLNL guidelines, or it is shipped to an off-site treatment or disposal facility. Liquids containing radioactivity are handled on site and may be treated using processes that reduce the activity to levels well below DOE Order 5400.5 requirements.

LLNL's sanitary sewer discharge permit requires continuous monitoring of the effluent flow rate and pH. A flow-proportional composite sampler collects samples that are analyzed for metals, radioactivity, toxic chemicals, and water quality parameters. In addition, the outflow to the municipal collection system is sampled continuously and analyzed in real-time for conditions that may upset the LWRP treatment process or otherwise impact the public welfare. The effluent is continuously analyzed for pH (as mentioned above), selected metals, and radioactivity. If concentrations above warning levels are detected, an alarm is registered at the LLNL Fire Dispatcher's Station, which is attended 24 hours a day. The monitoring system provides a continuous check on sewage control and, since July 1990, automatically notifies the LWRP in the event that contaminants are detected. Trained staff respond to all alarms to evaluate the cause.

Two major upgrades were made to the continuous monitoring system in the last quarter of 1994. First, the centrifugal sampling pumps were replaced with a vortex-impeller sampling pump. The new pump is markedly more reliable in providing a continuous sampling stream. Secondly, the electrical system was rewired. The result of the rewiring is a significantly more dependable and maintainable electrical system.

On the basis of the continuous monitoring data, during 1994 there was one release of a metallic contaminant above the warning levels (see the Environmental Impact section of this chapter) and no releases of corrosive or radioactive contaminants that warranted a sewer diversion. This is consistent with the results for 1993, when no such releases were detected, and contrasts markedly with the results for 1991 and 1992, when 15 and 13 such releases, respectively, were detected.

In 1991, LLNL completed construction of a diversion system that is automatically activated when the monitoring system sounds an alarm. The diversion system ensures that all but the first few minutes of the affected wastewater flow is retained at LLNL, thereby protecting the LWRP and minimizing any required cleanup. Up to 775,000 liters of potentially contaminated sewage can be held pending analysis to determine the appropriate handling method. The diverted effluent may be returned to the sanitary sewer (if the liquid is not hazardous or after the contamination level is adjusted, depending on analytical results), shipped for off-site disposal, or treated at LLNL's Hazardous Waste Management Facility. All diverted sewage in 1994 was returned to the sanitary sewer.

In 1991, LLNL completed the implementation of a system of satellite monitoring stations that operates in conjunction with the sewer monitoring system (**Figure 5-1**). The satellite monitoring stations are positioned at strategic locations within the main sewer system to help pinpoint the on-site area from which a release might have originated. Each station consists of an automatic sampler that collects samples on a time-proportional basis. If there is a release, these samples are analyzed. However, early in 1994, all but two (86B and 51A) of the satellite monitoring stations were taken off-line until the equipment used in routine maintenance of the stations can be ergonomically reengineered.

Methods

A 24-hour composite of Livermore-site sewage effluent is collected daily by a peristaltic pump that functions for 4 seconds for every 3785 liters of effluent. Aliquots of this composite are transferred to polyethylene bottles and submitted for analysis. Treated effluent from LWRP is collected daily by LWRP employees. The daily 500-milliliter aliquots are composited in one gallon polyethylene bottles, which are collected weekly by LLNL. Composite samples from the LWRP digesters are collected monthly. The composites consist of aliquots taken from the circulating sludge once a week.

Standard quality control and quality assurance procedures are followed. When each sewage field sample is collected, it is labeled with the sampling location and date of sampling. In the laboratory, each sample is assigned a number that accompanies that sample during analysis.

The daily composite samples are analyzed for gross alpha, gross beta, and tritium activity. A monthly composite of the Livermore-site and LWRP effluents is analyzed for ^{137}Cs and ^{239}Pu using ion-exchange and gamma or alpha spectroscopy (respectively). Weekly composites of LLNL effluent are analyzed for metals. In addition, composite samples from the LWRP digesters are analyzed

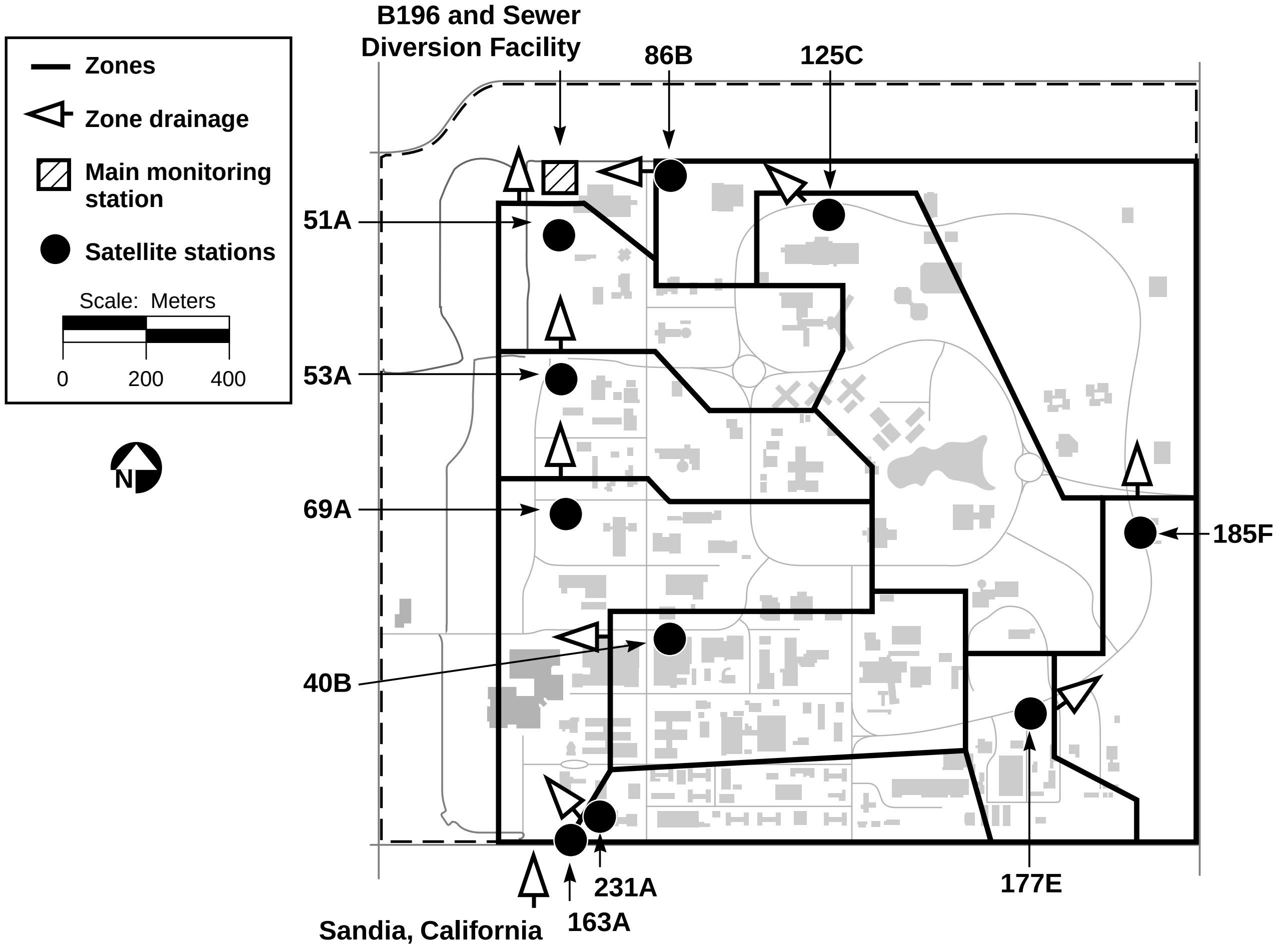

Figure 5-1. Sewer monitoring network.

monthly for gross radioactivity and metals; composites of the monthly samples are analyzed quarterly for plutonium, cesium, and gamma-emitting radionuclides.

Water quality parameters and organic compounds are also monitored. Once each month, a 24-hour composite sample and an instantaneous grab sample of the LLNL sewage effluent are subjected to an extensive set of analyses. These analyses include parameters specified on LWRP’s National Pollutant Discharge Elimination System permit, including metals, nutrients, pesticides, and priority pollutants. The federal priority pollutants are measured using EPA Methods 608, 624, and 625 to establish baseline information for these parameters. As part of this monthly sampling program, four oil and grease grab samples are acquired at 4-hour intervals during the day. The analytical results are averaged to obtain a representative measure of the daily oil and grease concentration.

Samples were collected at the point where specified metal finishing and electrical (and electronic) component processes are discharged to assure compliance with EPA categorical pretreatment discharge limits for those processes. The results are reviewed in Chapter 13, Compliance Self-Monitoring.

Three changes in the sampling program were made in 1994. In January, to minimize confined space access by sampling personnel, LLNL modified its monthly instantaneous grab sampling procedure. These samples are collected from the vault entrance using a portable sampler, instead of entering the vault to collect from the sewage stream with either a collimated water sampler (coliwasa) or a grab sample dipper. This change was implemented as a health and safety measure after determining that analytical results for the new sampling protocol were consistent with historical discharge characteristics. Secondly, from January through November, LLNL's secondary contractor for environmental analytical services performed the Biological Oxygen Demand analysis. This analytical test was shifted from primary to secondary analytical contractor while the primary analytical contractor resolved quality control issues with the Biological Oxygen Demand analysis. Finally, in September, pursuant to a LWRP request, LLNL began to measure the federal priority pollutants using EPA Methods 608, 624, and 625, instead of EPA Methods 624 and 625.

Radioactivity in Sewage Results

Determination of the total radioactivity released as tritium, alpha emitters, and beta emitters is based either on the measured radioactivity in the effluent or on the limit of sensitivity, whichever is higher (see **Table 5-1**). The combined releases of tritium, alpha, and beta radiation is 5.0 GBq (GBq = gigabequerels = 10^9 Bq), or 0.14 curie (Ci). The total is based on the results shown in **Table 5-1**, reduced by reported Sandia, California tritium releases of 2.2 GBq (0.06 Ci). The annual average concentration of tritium in LLNL sanitary sewer effluent was 0.011 Bq / mL (0.65 pCi / mL).

The concentrations of ^{239}Pu, ^{137}Cs, and tritium measured in the sanitary sewer effluent from LLNL and LWRP are presented in **Table 5-2**. The tritium numbers

Table 5-1. Estimated total radioactivity in sanitary sewer effluent, LLNL, 1994.

Radioactive Emitter	Estimate Based on Effluent Concentration (GBq)[a]	Limit of Sensitivity (GBq)[a]
Tritium	6.9[b]	4.4
Alpha radiation	0.094	0.092
Beta radiation	0.22	0.084

a GBq = 10^9 Bq or 0.027 Ci.

b 6.9 GBq includes 4.7 GBq from LLNL plus 2.2 GBq from Sandia, California.

Table 5-2. Various radionuclides in sanitary sewer effluents, LLNL and LWRP, 1994.

Month	^{3}H (mBq/mL) LLNL	^{3}H (mBq/mL) LWRP	^{137}Cs (μBq/mL) LLNL	^{137}Cs (μBq/mL) LWRP	^{239}Pu (nBq/mL) LLNL	^{239}Pu (nBq/mL) LWRP	^{239}Pu (mBq/dry g) LWRP sludge[(a)]
January	4.5 ± 0.3	<5.6	1.1 ± 0.4	<0.6	1130 ± 110	0.5 ± 13.9	
February	2.1 ± 0.2	<5.5	< 0.69	<0.6	360 ± 50	2 ± 6	
March	6.0 ± 0.4	<5.2	1.8 ± 0.4	<0.7	520 ± 80	–5 ± 11	1.9 ± 0.1
April	26 ± 1	<5.2	1.2 ± 0.4	<0.4	1000 ± 110	2 ± 10	
May	6.0 ± 0.5	<5.1	1.4 ± 0.5	<0.7	420 ± 60	5 ± 9	
June	3.9 ± 0.3	<5.2	1.1 ± 0.5	<0.6	90 ± 30	5 ± 5	0.44 ± 0.04
July	9.8 ± 0.7	<5.2	1.3 ± 0.4	<0.3	290 ± 50	6 ± 8	
August	5.1 ± 0.4	<4.9	1.5 ± 0.3	<0.5	190 ± 40	–6 ± 6	
September	28 ± 1	<4.9	<0.61	<0.4	210 ± 40	7 ± 9	1.2 ± 0.1
October	4.1 ± 0.3	<5.0	0.9 ± 0.3	<0.5	670 ± 80	0.3 ± 6.6	
November	20 ± 1	<5.1	0.9 ± 0.5	<0.4	560 ± 70	–4 ± 7	
December	5 ± 1	<5.0	1.0 ± 0.4	<0.6	270 ± 50	–1 ± 8	1.0 ± 0.1
Median	**6.0**	**<5.1**	**1.1**	**<0.5**	**390**	**1**	**1.1**
Interquartile range	**12.0**	**—[(b)]**	**0.5**	**—[(b)]**	**330**	**7**	**0.5**
	pCi/mL[(c)]						**pCi/dry g[(c)]**
Median	**0.16**	**<0.14**	**2.9×10^{-5}**	**$<14 \times 10^{-6}$**	**11×10^{-6}**	**0.3×10^{-7}**	**0.03**
Interquartile range	**0.32**	**—[(b)]**	**1.2×10^{-5}**	**—[(b)]**	**9×10^{-6}**	**1.8×10^{-7}**	**0.01**

Annual Total Discharges by Radioisotope

	^{3}H[(d)]	**^{137}Cs**	**^{239}Pu**	**Total**
Bq/y	**4.7×10^{9}**	**4.6×10^{5}**	**1.9×10^{5}**	**4.7×10^{9}[(c)]**
Ci/y[(c)]	**0.13**	**1.3×10^{-5}**	**5.2×10^{-6}**	**0.13**
Fraction of limit				
DOE	**1.6×10^{-5}**	**2.0×10^{-6}**	**1.1×10^{-6}**	**1.9×10^{-5}**
10 CFR	**0.026**	**1.3×10^{-5}**	**—**	**—**

Note: Radionuclide results are reported ±2σ; see Chapter 14, Quality Assurance.

a Sludge from LWRP digesters is dried before analysis. The resulting data indicate the plutonium concentration of the sludge prepared by LWRP workers for disposal at the Livermore Sanitary Landfill.

b Due to the large number of nondetections, the interquartile range is omitted. See Chapter 14, Quality Assurance.

c 1 Ci = 3.7×10^{10} Bq

d Not including Sandia, California discharges of 2.2×10^{9} Bq (0.0586 Ci).

are based on the flow-weighted average of the individual daily sample results for a given month. The plutonium and cesium numbers are the direct result of analysis of monthly composite samples of LLNL and LWRP effluent, and quarterly composites of LWRP sludge. At the bottom of the table, the total activity released is given by radioisotope. This was calculated by multiplying each sample result by the total flow volume over which the sample was collected, and summing up over all samples. The total activity released for each radio-isotope is a conservative value; the limit of sensitivity was used in the calculation when the limit of sensitivity was greater than the actual activity reported.

The historical trend in the monthly average concentration of tritium is shown in **Figure 5-2**. Also included in the figure is the DOE tritium limit (370 Bq / mL), discussed in the Environmental Impact section of this chapter. The trend plot in **Figure 5-2** is indicative of a well-controlled tritium discharge that is not necessarily driven by site inventory.

Figure 5-3 shows the average monthly plutonium and cesium concentrations in sewage since 1985. The annual average concentration of ^{137}Cs was 1.1 μBq / mL (3.0×10^{-5} pCi / mL); the annual average ^{239}Pu concentration was 0.46 μBq / mL (1.2×10^{-5} pCi / mL).

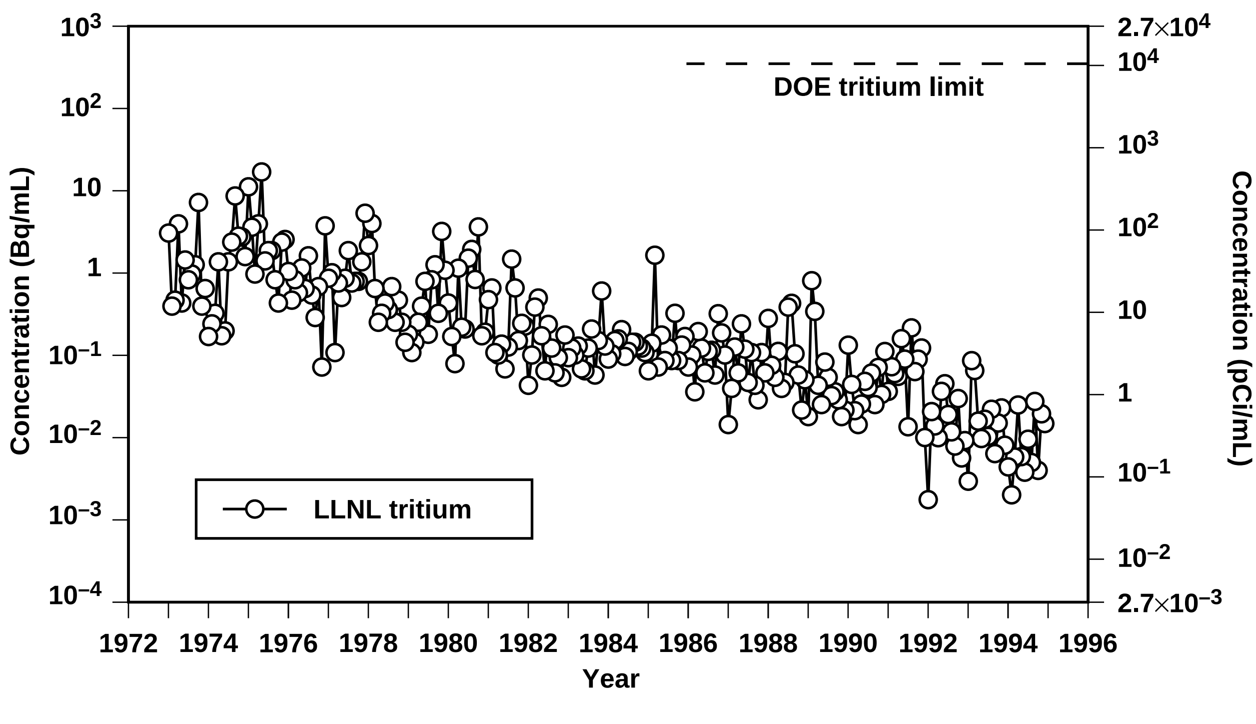

Figure 5-2. LLNL monthly average tritium concentration in sewage.

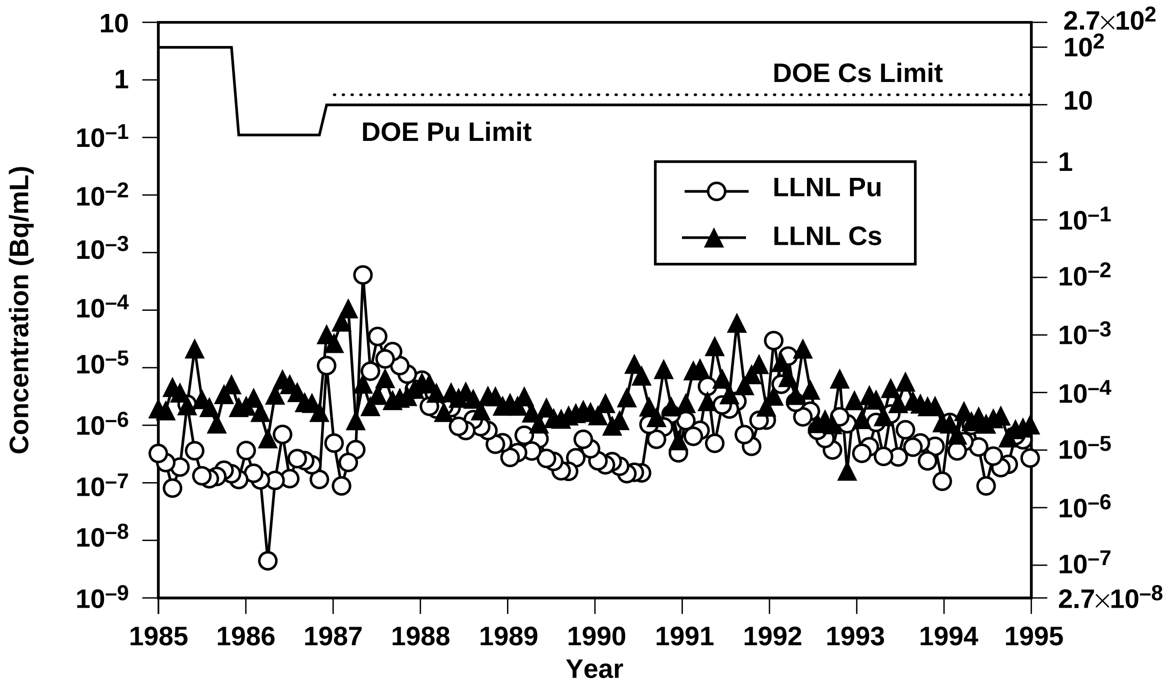

Figure 5-3. LLNL monthly average plutonium and cesium concentrations in sewage.

Nonradioactive Pollutants in Sewage Results

In July 1993, LLNL changed its primary nonradiological analytical laboratory. The transition between laboratories resulted in some fluctuation in the analytical limits of detection and minor inconsistencies in the reported suite of analytes; the majority of the fluctuations and inconsistencies were resolved by the end of the first quarter of 1994.

Table 5-3 presents monthly average metal concentrations in LLNL's sanitary sewer effluent. The averages were obtained by a flow-proportional weighting of the results from analysis of the weekly composite samples and the 24-hour composites collected each month. Each result was weighted by the total flow volume for the period during which the sample was collected. The results are quite typical of the values seen during previous years, with the exception of arsenic. The arsenic results are discussed below in the Environmental Impact section.

Results of monthly monitoring for metals and other physical and chemical characteristics of the sanitary sewer effluent are provided in **Table 5-4**. Note that—although the samples were analyzed for bromide, carbonate alkalinity (as $CaCO_3$), hydroxide alkalinity as ($CaCO_3$), nitrate (as N), beryllium, cyanide, and the full suite of organochlorine pesticides—those analytes were not detected in any sample acquired during 1994, and so are not presented in the table. The results are quite typical of those seen in previous years, with the exceptions of oil and grease and the purgeable-extractable pollutants.

Table 5-3. Metals discharged to sanitary sewer system (in mg/L), 1994 summary.

Month	Ag	Al	As	Be	Cd	Cr	Cu	Fe	Hg	Ni	Pb	Zn
January	0.009	0.47	0.0046	<0.0005	0.0031	0.024	0.07	3.30	0.0007	0.007	0.013	0.28
February	0.010	1.41	0.0040	<0.0005	<0.0029	0.021	0.07	2.27	0.0010	0.013	0.012	0.26
March	0.009	0.31	0.0023	<0.0005	0.0022	0.012	0.09	1.02	0.0006	0.007	0.012	0.16
April	0.010	0.70	0.0024	<0.0005	<0.0050	0.013	0.07	1.28	0.0006	0.008	0.013	0.17
May	0.012	0.40	0.0037	<0.0005	<0.0050	0.017	0.08	1.63	0.0009	0.006	0.019	0.16
June	0.013	0.42	0.0044	<0.0005	<0.0050	0.020	0.10	1.31	0.0006	0.008	0.018	0.18
July	0.011	0.52	0.0042	<0.0005	<0.0050	0.013	0.13	1.11	0.0007	0.006	0.026	0.19
August	<0.010	0.58	0.0057	<0.0005	<0.0050	0.013	0.10	0.96	0.0004	0.006	0.019	0.15
September	<0.010	0.45	0.0039	<0.0005	<0.0050	0.012	0.12	1.11	0.0003	0.006	0.033	0.20
October	<0.010	0.30	0.0032	<0.0005	<0.0050	0.012	0.07	0.85	0.0003	0.007	0.015	0.16
November	<0.010	0.23	0.0035	<0.0005	<0.0050	0.018	0.06	0.87	0.0007	0.006	0.007	0.13
December	0.010	0.27	0.0022	<0.0005	<0.0050	0.010	0.06	0.77	0.0002	0.006	0.010	0.12
Median	**<0.010**	**0.44**	**0.0036**	**<0.0005**	**<0.0050**	**0.013**	**0.08**	**1.11**	**0.0006**	**0.007**	**0.014**	**0.17**
IQR	**0.001**	**0.22**	**0.0014**	**—**[a]	**—**[a]	**0.006**	**0.03**	**0.45**	**0.0003**	**0.001**	**0.007**	**0.04**
DCL[b]	**0.2**	**—**[c]	**0.06**	**—**[c]	**0.14**	**0.62**	**1.0**	**—**[c]	**0.01**	**0.61**	**0.2**	**3.0**
Fraction of DCL	**0.05**	**—**[c]	**0.06**	**—**[c]	**0.04**	**0.02**	**0.08**	**—**[c]	**0.06**	**0.01**	**0.07**	**0.06**

a Due to the large number of nondetects, the interquartile range could not be calculated for these analytes. See Chapter 14, Quality Assurance.

b Discharge Concentration Limit (City of Livermore Ordinance 13.32).

c No established limit for analyte.

Table 5-4. Positively detected parameters in LLNL sanitary sewer effluent, 1994.

Positively Detected Parameter	Detection[(a)] Frequency	Minimum	Maximum	Median	IQR[(b)]
Physical and Chemical (mg/L)					
Biochemical oxygen demand	12/12	75	300	140	73
Chemical oxygen demand	12/12	120	630	335	133
Solid settling rate (mL/L/h)	11/11	2	28	17	11
Total dissolved solids (TDS)	12/12	190	290	250	40
Total suspended solids (TSS)	12/12	51	220	115	56
Volatile solids	11/11	11	160	63	42
Bicarbonate alkalinity (as $CaCO_3$)	12/12	110	200	160	60
Total alkalinity (as $CaCO_3$)	12/12	110	200	160	60
Chloride	12/12	31	95	45	14
Sulfate	12/12	11	37	17	13
Nitrite (as N)	1/12	<0.1	<5	<0.5	—
Ammonia nitrogen (as N)	11/12	<0.1	51	34	16
Total Kjeldahl nitrogen	11/11	30	63	44	15
Total phosphorus (as P)	12/12	0.079	11	3.4	2.6
Ortho-phosphate	3/3	9.6	19	12	4.7
Aluminum	10/12	<0.2	1.1	<0.30	0.22
Arsenic	5/12	<0.002	0.005	<0.002	—
Cadmium	2/12	0.0019	<0.005	<0.005	—
Calcium	12/12	7.9	25	14	3.5
Chromium	7/12	<0.01	0.042	<0.014	0.0055
Copper	12/12	0.059	0.26	0.077	0.019
Iron	12/12	0.42	2.7	0.89	0.43
Lead	12/12	0.0076	0.046	0.013	0.0055
Magnesium	12/12	2.0	4.7	3.0	1.4
Mercury	7/12	<0.0002	0.0014	<0.0003	0.00038
Nickel	6/12	<0.005	0.01	<0.005	—
Potassium	11/12	<0.5	19	<15	2.8
Selenium	3/12	<0.002	0.003	<0.002	—
Silver	6/12	0.0072	0.055	<0.010	—
Sodium	12/12	25	48	38	8.5
Zinc	12/12	0.094	0.34	0.185	0.045
Organic Compounds (mg/L)					
Oil and grease	12/12	6.9	274	21	6.6
Phenolics	5/12	<0.01	<0.05	<0.013	—
Total organic carbon (TOC)	12/12	29	96	46	23

Table 5-4. Positively detected parameters in LLNL sanitary sewer effluent, 1994 (concluded).

Positively Detected Parameter	Detection[(a)] Frequency	Minimum	Maximum	Median	IQR[(b)]
Purgeable/Extractable Pollutants (EPA Methods 624 and 625, μg/L)					
Acetone	8/12	<10	770	<52	57
Benzoic acid	4/12	<50	<500	<63	—
Benzyl alcohol	5/12	<20	<200	<30	—
Bis(2-ethylhexyl)phthalate	9/12	<10	<100	<12.5	10.75
Chloroform	12/12	7.4	29	11	4.5
Di-n-butylphthalate	3/12	<10	150	<10	—
Diethylphthalate	1/12	<10	<100	<10	—
m- and p-Cresol	1/12	<10	<100	<10	—
Methylene chloride	1/12	<1	1500	<1	—
Phenol	1/12	<10	<100	<10	—
Styrene	7/12	<1	170	<1	27
Toluene	1/12	<1	3.1	<1	—
Trichloroethene	2/12	<0.5	1.9	<0.5	—

a The number of times an analyte was positively identified, followed by the number of samples that were analyzed (generally 12, one sample for each month of the year).

b Where the detection frequency is less than 50%, the interquartile range is omitted.

Environmental Impact of Radioactivity in Sewage

During 1994, there were no inadvertent releases that exceeded any discharge limits for release of radioactive materials to the sanitary sewer system.

In 1990, DOE suggested that radiological releases to the sanitary sewer comply with local and state regulations. The most stringent of these limits was applied by Title 17 of the California Code of Regulations. As a federal facility, LLNL is formally exempt from the requirements of state regulations but follows those requirements under the guidance of DOE. Title 17 contained a limit on discharges of radioactivity in sewage of 37 GBq (1 Ci) each year; it also listed limits on the daily, monthly, and annual concentration for each specific radionuclide. In 1994, Title 17 was repealed and the discharge requirements of Title 17 were replaced with those found in Title 10 of the Code of Federal Regulations, Part 20. Title 10 contains a limit for the total discharge activity of tritium (185 GBq or 5 Ci), carbon-14 (37 GBq or 1 Ci), and all other radionuclides combined (37 GBq or 1 Ci); in addition, it specifies that the discharge material must be soluble and lists limits on monthly concentrations.

Table 5-5 summarizes the discharge requirements of Title 10. Because Title 10 permits and therefore applies to only soluble discharges, and because the plutonium in LLNL effluent is in the insoluble form, there is no applicable discharge requirement for ^{239}Pu. This assumption is supported by the

Table 5-5. Sewer discharge release limits for ^{3}H, ^{137}Cs, and ^{239}Pu.

	^{3}H	^{137}Cs	^{239}Pu
10 CFR 20 concentrations used to establish release limits	370 Bq/mL	0.37 Bq/mL	NA[(a)]
10 CFR 20			
Monthly	185 GBq	13 GBq	—
Yearly	185 GBq[(b)]	37 GBq[(c)]	—
DOE annualized discharge limit for application of BAT[(d)]	370 Bq/mL	0.56 Bq/mL	0.37 Bq/mL

a 10 CFR 20 imposes a discharge limit for soluble ^{239}Pu released. Evidence supports the insolubility of LLNL's plutonium discharges. Refer to the Environmental Impact section of this chapter.

b 10 CFR 20 imposes a 185-GBq (5-Ci) limit for the tritium radiation released.

c 10 CFR 20 imposes a 37-GBq (1-Ci) combined limit on the total of all radiation released (excluding tritium and ^{14}Ca, which have separate 10 CFR 20 limits of 185 GBq and 37 GBq, respectively); i.e., the total release of all isotopes must not exceed 37 GBq. If a total of 37 GBq of a particular isotope were released during the year, this would require that no other isotopes be released.

d The DOE annualized discharge limit for application of Best Available Technology (BAT) is five times the Derived Concentration Guide (DCG; ingested water) for each radionuclide released.

experience during the recent sewer system evaluation, when increased cleaning led to higher plutonium concentrations in LLNL sewage (Gallegos et al. 1993). This indicates that the bulk of plutonium discharged is liberated from deposits on the sewer pipes, which are, by their nature, insoluble.

Table 5-5 also includes the total activity that could have be discharged by LLNL during a given period (monthly and annually) assuming the 1994 average monthly flow rate. As the table clearly demonstrates, the Title 10 concentration limits for tritium for facilities such as LLNL that generate wastewater in large volumes are overridden by the limit on total tritium activity discharged during a single year. In 1994, the total LLNL tritium release was 2.6% of the corresponding Title 10 limit. Total LLNL releases (**Table 5-1**), in the form of alpha and beta emitters (excluding tritium), were 0.85% of the corresponding Title 10 limit.

DOE has also established criteria for the application of Best Available Technology to protect public health adequately and minimize degradation of the environment. These criteria (the Derived Concentration Guides, or DCGs) limit the concentration of each specific radionuclide that is discharged to publicly-owned treatment works. If a measurement of the monthly average concentration of a radioisotope exceeds its concentration limit, LLNL would be required to improve discharge control measures until concentrations were again below the DOE limits. **Table 5-5** presents the DCGs for the specific radioisotopes of most interest at LLNL.

The annual average concentration of tritium in LLNL sanitary sewer effluent was 0.000030 (that is, 0.0030%) of the DOE DCG (and the Title 10 limit); the annual average concentration of ^{137}Cs was 0.0000020 of the DOE DCG (and 0.0000030 of the Title 10 limit); and the annual average ^{239}Pu concentration was 0.0000012 of the DOE DCG. The combined discharges were therefore 0.000033 of the DCG. As discussed earlier in this section, when calculating the contribution from plutonium, the plutonium in LLNL effluent is assumed to be in the insoluble form (the DCG for soluble forms of plutonium is 70 times less than the DCG for insoluble plutonium).

LLNL also compares annual discharges against historical values to evaluate the effectiveness of ongoing discharge control programs. **Table 5-6** summarizes the radioactivity in liquid effluent released over the past ten years. During 1994, a total of 6.9 GBq (0.19 Ci) of tritium was discharged to the sanitary sewer. This is the combined release from the Livermore site and from Sandia, California, whose records account for 2.2 GBq (0.06 Ci) of this amount; LLNL therefore released 4.7 GBq (0.13 Ci), an amount that is well within environmental protection standards and is less than the range reported in the past. Note that DOE did not suggest compliance with the 37 GBq limit of Title 17 until 1990.

Figure 5-3 summarizes the ^{239}Pu monitoring data over the past ten years. The historical levels observed since 1985 are approximately 0.37 µBq/mL (1×10^{-5} pCi/mL), with the exception of a peak in 1987. Even this peak is well below the applicable DOE DCG. Historically, levels generally are one-millionth (0.000001) of that limit. The greatest part of the plutonium discharged in LLNL effluent is ultimately concentrated in LWRP sludge, which is dried and disposed of at a landfill. The plutonium concentration observed in 1994 sludge (**Table 5-2**),

Table 5-6. Radioactive liquid effluent releases from the Livermore site, 1985–1994.

Year	Liquid Effluents (GBq)	
	^{3}H (LLNL and Sandia, California)	^{239}Pu
1985	133	1.8×10^{-4}
1986	74	5.5×10^{-4}
1987	52	2.6×10^{-2}
1988	56	8.1×10^{-4}
1989	59	1.8×10^{-4}
1990[a]	25	2.3×10^{-4}
1991	32	6.1×10^{-4}
1992	8	1.9×10^{-3}
1993	12.6	2.6×10^{-4}
1994	6.9	1.9×10^{-5}

[a] Year that DOE first suggested compliance with the 37-GBq (1-Ci) limit of California Title 17.

1.1 mBq / dry g (0.03 pCi / dry g), is more than 400 times lower than the proposed EPA guideline for unrestricted use of soil (480 mBq / dry g).

As first discussed in the *Environmental Report for 1991* (Gallegos et al. 1992a), plutonium and cesium concentrations were slightly elevated during 1991 and 1992 over the lowest values seen historically. As was established in 1991, the overall upward trend is related to sewer cleaning with new, more-effective equipment. During 1993, as utility personnel worked to complete an assessment of the condition of the sewer system, cleaning activity around the site was less extensive, resulting in slightly lower plutonium and cesium concentrations in LLNL effluent. During 1994, in conjunction with the installation of the synthetic sock lining in the sewer system, the cleaning activity around the site was more extensive than in 1993. However, by the end of 1993, the new sewer cleaning equipment had been used on LLNL's entire sewer system; this has been reflected in 1994 by the continuation of the slightly lower plutonium and cesium concentrations that were observed in the 1993 effluent.

Environmental Impact of Nonradioactive Liquid Effluents

Table 5-3 presents monthly average metal concentrations in LLNL's sanitary sewer effluent. At the bottom of the table, the annual average concentration for each metal is compared to the discharge limit. The metals that approached closest to the discharge limits were copper and lead at 8% and 7%, respectively, of the discharge concentrations.

Although arsenic concentrations were well below discharge limits, the slightly elevated levels first seen during the summer of 1992 continued through 1994. As first discussed in the *Environmental Report for 1993* (Gallegos et al. 1994), the elevated arsenic levels were the subject of an extended investigation during 1993. The conclusion of the 1993 investigation was that the ground water restoration operation at a gas pad seemed to account for the majority of the observed arsenic. The gas pad cleanup operation continued in 1994, and the slightly elevated arsenic levels of 1993 continued in 1994.

Table 5-4 presents the results of monthly monitoring for metals and other physical and chemical characteristics of the sanitary sewer effluent. The results are quite typical of those seen in previous years, with the exceptions of oil and grease and the purgeable-extractable pollutants.

As a whole, the reduced concentrations of oil and grease observed in 1993 continued in 1994. (The overall oil and grease concentrations are substantially reduced from levels in 1992, when LLNL received a Notice of Violation for grease discharges. As a result of this incident, LLNL adopted the LWRP's suggested changes in sampling protocol and implemented improvements in the design of grease abatement measures in use at LLNL cafeterias.) The exception to the substantial reduction in oil and grease concentrations is observed in the maximum value (274 mg/L) for 1994; however, this result was not confirmed with analysis of a duplicate sample. Nonetheless, EPD conducted seminars on proper food-handling and disposal practices for the employees of the LLNL cafeterias.

Overall, the results for the purgeable-extractable pollutants are typical of those seen in prior years. However, there are two notable exceptions. The first exception is for styrene. Styrene was not detected in previous years but was observed in approximately 60% of the 1994 monthly samples. We attribute the presence of styrene to the relining of the sewer system with synthetic socks. The detection of styrene occurred during the relining work, and the resin-impregnated synthetic socks contain styrene. The second exception is for methylene chloride. In a monthly sample for January 1994, there was a sufficient concentration of methylene chloride to cause LLNL to exceed the effluent pollutant limitations of its sewer permit and receive a Notice of Violation. As a result of this incident, the LWRP suggested additional EPA Method 624 sampling (methylene chloride is in the suite of compounds analyzed for in EPA Method 624) that could demonstrate that the single monthly instantaneous grab sample was not representative of that entire month's discharge profile. In response to the LWRP's suggestion, LLNL collects two EPA Method 624 samples on the day of the monthly sample collection; the sample collected earliest in the day is submitted for analysis, and the later sample is held pending the analytical results for the earlier sample.

The continuous monitoring system detected one inadvertent discharge during 1994 (as compared to 0 and 13 such discharges in 1993 and 1992, respectively); this incident was reported to the LWRP and DOE. Specifically, in January 1994, the continuous monitoring system detected a brief discharge of zinc above alarm limits. The instantaneous concentration was 3.3 mg/L, and the average concentration for the 31-hour period containing the release was 0.6 mg/L, as compared to 3.0 mg/L, the effluent pollutant limit for zinc contained in LLNL's sewer permit. The estimated duration of the incident was 25 minutes. Since this incident lasted more the five minutes, the Sewer Diversion Facility was activated to contain the remainder of the release. (If a release lasted as long as 24 hours, concentrations above the effluent pollutant limit could disrupt treatment plant operations or cause the treated wastewater to exceed allowable concentration limits for discharge to the San Francisco Bay.) Later analysis of the diverted effluent showed that the average concentration of zinc was sufficiently low to allow release of the wastewater back to the sanitary sewer. This incident did not represent a threat to the integrity of the operations at the LWRP.

Through investigation of the zinc discharge incident, it was determined that the source of the zinc was from the cooling tower sludge released to the sanitary sewer during cooling tower cleanout. As a result of this zinc discharge incident, the method for cleaning cooling tower has been modified to further minimize the introduction of the sludge into the sanitary sewer system.

The sewage monitoring data for 1994 reflect the success of LLNL's discharge control program in preventing any significant impact on the operations of the City's treatment plant. The results demonstrate good compliance with the effluent pollutant limitations of LLNL's sewer permit, and are generally consistent with values seen in the past.